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A NEW LACERATION PREDICTION SYSTEM

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Background

As the quantity of injury research data grows, the need for accurate, reproducible methods of measuring soft tissue damage potential also increases. Systems to measure facial laceration potential have not kept up with the development of more precise measuring systems in other areas of impact testing. The use of chamois to represent skin/tissue does not give accurate and repeatable results.

The chamois method involves covering dummy headforms with two chamois skins to roughly represent human skin. Commonly, the chamois is moistened and applied over an underlying layer of rubber. This method has limitations. First, some amount of subjective assessment is inevitable. It is a simple pass/fail system, with pass indicating slight abrasions and lacerations and fail indicating that cuts have appeared in the inner of the two layers. This supplies a good but rough estimate, but includes no detailed data about the nature of the laceration. Also, a natural material like chamois cannot be manufactured for consistency and will always vary in thickness and other characteristics, and thus will not allow tests to be accurately repeated. Finally, chamois is not applied to the heads in a uniform way by different researchers, which also affects test results.

A search by the University of Virginia of the NASS accident report data bases (1990-91 combined) indicate that soft tissue injury occurs in about 65% of the cases (with AIS-1 or greater) where the occupant is restrained. The effects of air bag deployment are just beginning to appear in NASS data bases. While there appear to be shifts in the number and source of soft tissue damage, soft tissue damage still occurs in about 45% of the cases with AIS-1 or greater.

Methods of Judging Injury Severity

Many methods of judging laceration and injury potential have been used in conjunction with the chamois skins. They include the Gadd Severity Index [Gadd, 1966], the Head Injury Criterion [National Highway Safety Administration, 1972], the Chamois Laceration Scale (CLS) [Jettner, 1986] and the Corning Scale [Blizard]. With each of these method, measuring laceration potential has been based on skilled *subjective* judgement. All the scales present a list of criteria to measure laceration, but in no case does the criteria cover all eventualities. Also, by their very nature, the scales allow the engineer to interpret the scales either very rigidly or quite flexibly, resulting in laceration scores that can vary greatly from investigator to investigator.

The Triplex Laceration Index (TLI), developed in the early 1970s [Pickard], gives researchers a way to quantitatively assess the severity of lacerations when using two layers of chamois and an underlying rubber layer. TLI's simple mathematical formula correlates the number, length, and depth of cuts in the chamois to a level of laceration severity in human skin. Relying only on definite physical measurements, the objective TLI measuring system does not rely on subjective judgement.

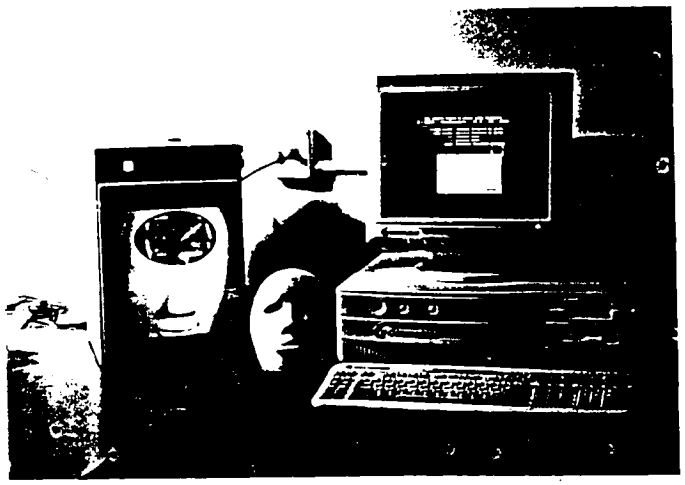

Figure 1. Face mask laceration system.

Going Beyond Chamois

The Department of Transportation has funded research at TRDC to develop and test an innovative system to measure the potential for facial laceration during vehicle crashes [2,3]. The system developed under the SBIR program consists of two major elements: an elastomeric face mask installed over a Hybrid III dummy head and a machine vision system that automatically quantifies the extent of laceration damage to the face mask after experimental impacts. This system not only will provide a more accurate way to assess soft tissue damage, it takes a major new direction by going beyond the chamois manikin head covering. The major components of the system are shown in Figure 1.

Artificial Skin Mask
Fabrication and Test Drops

The mask that will replace chamois is expected to be significantly more consistent than chamois. It addition, it should be possible to manufacture the mask at a reasonable cost.

The mold for fabricating the face mask was developed for the male Hybrid III head using molding techniques developed specifically for this project.

In selecting the face mask material (the artificial skin), many compounds were tested, including various composites of thermoset silicone and polyurethane with combinations of woven mats, threads, and other fillers. These tests helped in the formulation of the elastomer for the mask material. Ultimately, a two-part thermoset silicone exhibited the best potential for fabricating a face mask for measuring laceration potential. Face masks were molded using thermoset compounds blended according to special procedures and formulas. This viscous material was pressure-injected into the mold and cured.

The first mask fabricated was front facial only. Velcro fasteners were added to this mask to attach it to the Hybrid III head. Researchers decided not to add tightening/attachment means in the second mask, which was a full head. Drop tests were conducted to determine the dynamic impact changes caused by the masks and by the double-layer chamois. In the drop tests, a 6.81-kilo instrumented Hybrid III head traveling 24.14 kilometers per hour impacts a solid object. The full and half artificial-skin masks had slight and no effect, respectively, on the dynamic impact response of the male Hybrid III dummy head. The effect of the full mask is approximately the same impact as noted with two layers of chamois on the Hybrid III head form.

Drop tests also were conducted to provide a basis to compare the laceration characteristics of the new mask materials with those of human skin and chamois. The test bed used for the drop tests permitted data to be collected that plotted cut depth against peak force generated per unit edge length. To calibrate the system, many drop tests were performed on chamois and the results compared to data from the University of Birmingham (UB), England. The UB data was used because it is the most extensive testing available for comparison to chamois and human soft tissue. Copious test results using the chosen method are available for comparison, an important criterion if the new mask is to be accepted as a viable alternative to chamois.

Hundreds of drop tests were performed at TRDC and UVA on double layer chamois and on the elastomer material, and a number of modifications and calibrations made to produce approximately the same results as UB researchers. Head drop tests and evaluations of the face masks and double layers of chamois mounted on Hybrid III headforms at The University of Virginia indicated that the dynamic performance and laceration damage was similar for both methods. The face mask did not shift or slip during these tests.

Vision System

After an impact test, the damaged mask is removed from the manikin head and put placed on a translucent headform. A CCD (charged coupled device) camera is mounted a fixed, specific distance from the headform. This camera records the number, length, and depth of each laceration as the head is rotated. (The headform is mounted on a pivot to permit several camera viewing angles). The data is processed by optical imaging techniques, then fed into an analyzing program that determines the severity of the injuries. The camera vision system then determines the number and length of each laceration to calculate measures such as the Triplex Laceration Index.

Experimentation was conducted using a commercially available image processing toolbox that supports several standard image processing techniques such as contract enhancement (including

sliding and stretching), spacial filtering (including both convolution and non-convolution filters), histogram equalization, contouring, thresholding, and various mathematical image combination operators. Image processing can be judged for applicability to the laceration recognition task without requiring that each algorithm be developed and tested from scratch. The most promising algorithms were then coded to run at increased speed for inclusion into TRDC's program.

This system permits tissue damage to be accurately and repeatably measured and reduces the variability of results, which has been a problem with the chamois method. Additional information, test results, and more details will be included in the final report to the Department of Transportation, which should be delivered during November. We also intend to publish the results of the program in the future.

The vision system software developed during the program was devised specifically to be used with prototype facial masks on the headforms. However, the software was designed with modular flexibility to allow it to be quickly adapted to evaluate other manikin components.

Further development efforts should allow the technology to be used in many other applications, such as on Hybrid III chest and legs, the torso of the Side Impact Dummy (SID), and the head of Advanced Dynamic Anthropomorphic Manikin for assessing aircrew injury potential during canopy ejection tests (ADAM) for the canopy eject tests. TRDC has teamed with First Technology Safety Systems of Plymouth, Michigan (a world leader in the manufacture of anthropomorphic manikins) to bring the technology to market.

References

Gadd, C.W. Use of a weighted-impulse criterion for estimating injury hazard. Proceedings, the 10th STAPP Car Crash Conference, 1966.

National Highway Traffic Safety Administration. Department of Transportation Motor Vehicle Safety Standard, No. 208. Docket 69-7 as amended by Notice 23 (37 F.R. 22871 - October 26, 1972).

Blizard, J. R. and J.S. Howitt. A new laminated windshield designed to minimize laceration. SAE 700428.

Jettner, E. Facial Laceration Measurements, SAE Paper #860198, 1986.

Pickard, J., P. Brereton, and A. Hewson. Proceedings of Seventeenth Conference of the American Association of Automotive Medicine, November 1973.

McKinney, R. and D. Moody. A new "artificial skin" face mask for measurement of laceration potential. Proceedings, Soc Plastics Engineers ANTEC Conference, Detroit, MI, May 1992.

McKinney, R. Facial mask to measure laceration potential. Final Report, US Department of Transportation, Contract DTRS-57-90-C-00111, 1991.

DISCUSSION

PAPER: **A New Laceration Prediction System**

PRESENTERS: Richard McKinney, Triangle Research and Development Corporation

Q: Tony Sances, Medical College of Wisconsin
Have you been able to compare your results with those of cadaveric tests?

A: The University of Virginia did do some tests with the dart drops onto some cadavers, and onto headforms with a chamois cover, and with the face mask in place. We do have that data, but it hasn't been thoroughly analyzed and will be presented hopefully in our final report to DOT. Hopefully, UVA and we can present something next year on the complete analysis of those tests. But it is correlated back to the work in the 70's in the UK and France, so we're in the same ballpark as far as a cut strength.

Q: What was the thickness of your material that you used?

A: We did a laser digitization and it was held to a two millimeters uniform right over the whole skin, although I think we have a molding problem. There is a little extra thickness at the chin right now, but that's a production problem.

Q: And the material is what?

A: It is a silicone base material.

Q: Thank you very much.